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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 701

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. September 20, 1918

THE CHEMICAL ANALYSIS OF WHEAT-FLOUR SUBSTITUTES AND OF THE BREADS MADE THEREFROM.

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OBJECT OF THE INVESTIGATION.

At present great interest is manifested in the subject of bread, as well as the various kinds of flour from which it can be made. Methods of making several varieties of bread, together with the place in the dietary occupied by bread, have been studied by the department and the results have been published.[1] This bulletin gives the results of the analyses of more than 30 part substitutes for wheat flour and the bread made from them. As very few authentic analyses of American bread materials and breads made with wheat-flour substitutes have been published, the results given here undoubtedly will be of value to millers, bakers, and housewives throughout the country.

ANALYTICAL WORK.

CHARACTER OF FLOURS AND BREADS ANALYZED.

Bread, as the unqualified term is understood generally in the United States, is the product made from wheat flour, salt, and water (with or without the addition of sugar, milk, etc.), leavened with yeast. The many other kinds of bread, such as rye bread, corn bread, salt-rising, and hot or baking-powder bread, usually are known by qualifying names to distinguish them from bread made entirely of wheat flour with yeast.

[1] U. S. Dept. Agr. Farmers' Buls. 807 and 955.

Wheat flour always has been held in high favor as the principal ingredient of bread, because in the presence of water the protein of wheat yields a tenacious and elastic substance, called gluten, which has the property of expanding during fermentation, thus forming a network of cellular air spaces throughout the dough. During the baking process the gluten is so altered, or "set," that the cellular structure is retained, as a result of which there comes from the oven a light, porous loaf, unlike that produced from any other cereal flour.

FLOUR.

Standard flour.—As the experiments herein reported were carried on intermittently over a period of three years, it was impossible to obtain the same standard wheat flour for the entire series. Consequently the standard flour, which formed three-fourths of the flour content of the breads analyzed, varied in its composition. The flour used in making the loaf here designated as the standard contained 12.50 per cent protein (N×6.25), while the protein content of the bread of this standard loaf as analyzed was 8.74 per cent. Other wheat flours used in admixture with the substitutes considered in the course of this work varied in their protein content from 11.38 to 12.63 per cent, the breads naturally showing a corresponding variation in the protein content. This accounts for some apparent discrepancies in the protein content of the breads made with 3 parts of wheat flour to 1 part of substitute.

The substitutes used in these experiments may be classified as follows:

Group 1: Substitutes of low protein content or high carbohydrate content. They include the starches from different sources; fruits, such as the banana; roots, such as the cassava; tubers, such as the potato and the dasheen; and nuts rich in carbohydrates, such as the chestnut.

Group 2: Substitutes obtained from grains and cereals. Among these are the common cereals, as well as buckwheat, grain sorghums, and millet.

Group 3: Substitutes obtained from the legumes, including the peanut.

Group 4: Substitutes obtained from certain by-products, like bran, wheat germ, cotton seed, peanut oil cake, and soy-bean oil cake. Most of these flours or meals were obtained from the trade.

A few of the experimental flours were prepared in the Fruit and Vegetable Utilization Laboratory of the Bureau of Chemistry in this way: For Irish potato flour, the potatoes were pared, sliced, cooked in steam for about five minutes, then dried, and finely ground. The sweet potato flour was prepared by cutting the roots into long thin slices, spreading them on trays to dry in a current of warm air

until thoroughly dry and brittle, and then passing the dried product through a small hand-power mill. For the banana flour, large green fruit was used. It was peeled by hand, sliced, dried, and ground into a flour.

Of those prepared in the Plant Chemical Laboratory the chestnut, dasheen (peeled and unpeeled), rice (polished and brown), millet, bean, pea, chick-pea, and soy bean were first thoroughly cleansed and then ground in a hand mill, while rye, feterita, kafir, milo, and kaoliang were scoured and then ground in an experimental mill to give the desired flours. To obtain the peanut meal, roasted peanuts were crushed with a rolling pin.

The potato flakes employed in these experiments were obtained from Germany several years ago. The boiled potatoes were prepared in the laboratory by boiling potatoes in their skins, after which they were cooled, peeled, and mashed.

BREAD.

All the breads analyzed in this investigation were made from mixtures of flour, in the proportion of 25 per cent of substitute to 75 per cent of standard wheat flour.[1]

METHODS OF ANALYSIS.

The methods for the analysis of cereal foods adopted by the Association of Official Agricultural Chemists [2] were used for all the determinations made, with the exception of the fat determination. As it is impossible to obtain accurate results for the estimation of fat in bread by the usual method of extraction, the Polenski method [3] was employed for this determination. The carbohydrates were obtained by difference. The calories per pound were calculated by multiplying the sum of the carbohydrates and protein by 1,860, and the fat by 4,220, and then adding the two results thus obtained.[4]

RESULTS OF THE ANALYSIS.

Table 1 gives the composition of the standard flour and of the substitutes. The composition of the breads, as analyzed on the air-dry basis, is given in Table 2, and, as calculated on the basis of an assumed average moisture content of 35 per cent, in Table 3. In a general way, the data in these three tables have been arranged in the order of the protein content of the flour. Those showing a low protein content come first, being followed in turn by those prepared from grains and cereals, then by those made from legumes, and, finally, by those from certain by-products. Besides giving the composition of the various flours and breads studied, the tables

[1] The bread was made according to the directions given in U. S. Dept. Agr. Farmers' Bul. 955.

[2] Jour. A. O. A. C., Aug. 15, 1916, Vol. II, No. 2, part 2: 187.

[3] Zt. Anal. Chem. 1911, *50:* 655.

[4] The calories were calculated by Rubner's factors.

show the nutritive value, in terms of calculated calories per pound, the color and texture of the loaf, and the amount of salt-free ash in the bread. Plates I to VII show very accurately the color and texture of the loaves of the different kinds of bread.

TABLE 1.—*Analysis of flour.*

Variety of flour.	P. C. No.	Water.	Ash.	Fat.	Fiber.	Protein (N×6.25).	Carbohydrates.	Calories per pound.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Group 1 (low protein content):								
Chestnut	13461	6.05	2.45	4.35	1.94	7.38	77.83	1,768
Cassava	10582	8.21	1.60	.29	2.01	1.44	86.45	1,628
Banana:								
Unripe	17259	7.85	2.65	.56	.87	4.04	84.03	1,661
Ripe	13174	2.35	2.96	1.03	.87	4.22	88.57	1,769
Dasheen:								
Unpeeled	13244	6.53	4.31	.60	2.33	8.25	77.98	1,629
Peeled	13245	7.48	4.12	.46	2.14	8.00	77.80	1,615
Potato:								
Dried	14659	6.82	4.01	.43	1.69	12.25	74.80	1,636
Flakes	14667	7.63	3.31	.29	1.75	5.70	81.32	1,630
Boiled	18086	80.72	.80	.05	.40	2.16	15.87	341
Starch	10608	13.69	.30	.12	.04	.35	82.83	1,552
Sweet potato	14671	5.98	3.42	.79	2.07	4.68	83.06	1,665
Group 2 (grains and cereals):								
Spring wheat	Standard.	12.00	.42	1.00	.25	12.50	73.83	1,647
Yellow corn:								
Raw	12883	6.96	.82	2.82	.69	7.88	80.83	1,768
Parched								
Steamed								
White corn:								
Raw	12884	7.21	.95	2.73	.79	8.25	80.07	1,758
Parched								
Steamed								
Rice:								
Polished	13485	9.65	.36	.24	.20	8.81	80.74	1,676
Brown	13603	10.20	1.07	1.47	.61	8.94	77.71	1,674
Buckwheat	13311	9.25	1.00	.92	.61	8.12	80.10	1,679
Rye (1.1 basis)	13495	8.67	1.45	1.75	1.42	15.60	71.10	1,686
Oatmeal	(1)	8.00	1.90	7.00	1.40	16.80	64.90	1,815
Feterita:								
Clear	14664	7.25	1.07	2.26	1.21	15.87	72.57	1,736
Patent	14663	8.02	1.04	1.87	.55	9.94	77.83	1,725
Millet	13625	11.19	.89	2.44	.51	14.94	72.03	1,683
Kafir	12291	11.38	1.43	2.59	1.00	14.12	69.48	1,664
Milo	12293	11.54	1.40	2.73	.91	13.37	70.05	1,667
Kaoliang	12292	11.41	1.57	3.04	1.03	13.31	69.64	1,671
Barley	17554	11.47	1.05	1.16	.45	8.69	77.18	1,636
Group 3 (legumes):								
Bean, white	13459	8.53	3.50	1.57	1.49	25.06	59.85	1,646
Pea, ordinary	13460	8.29	2.50	1.22	1.14	25.94	60.91	1,666
Chick-pea	14658	7.64	2.74	5.03	.99	20.44	63.16	1,767
Peanut	15325	2.82	2.18	49.40	1.54	29.31	14.75	2,905
Soy bean	13341	6.14	5.24	20.71	1.72	39.56	26.63	2,105
Group 4 (by-products):								
Bran	13306	7.86	5.26	2.90	6.22	18.00	59.76	1,550
Wheat germ	13755	6.92	5.42	10.64	2.17	32.63	42.22	1,859
Cotton seed, treated	12606	4.57	5.56	9.68	4.88	50.56	24.75	1,818
Peanut oil cake	18296	8.01	4.14	10.20	3.38	56.06	18.21	1,811
Soy-bean oil cake		6.25	5.97	5.93	4.37	45.45	32.03	1,691

[1] The average composition of oatmeal as given by König, et al.

TABLE 2.—*Analysis of bread, on the air-dry basis.*

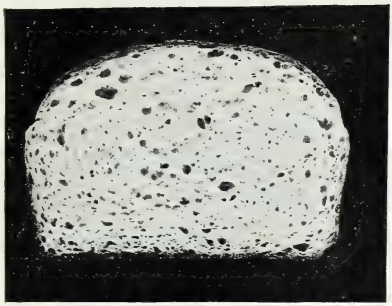
Variety of flour.	P. C. No.	Water.	Ash.	Fat.	Fiber.	Protein (N×6.25).	Carbohydrates.	Calories per pound.	Moisture in fresh bread.
Group 1 (low protein content):		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*
Chestnut	13492	6.47	2.38	2.26	0.58	11.75	76.56	1,731	.....
Cassava	13352	6.72	2.23	2.28	.58	10.50	77.69	1,729	37.29
Banana:									
Unripe	13347	6.20	2.57	2.02	.41	10.56	78.24	1,740	38.22
Ripe	13348	7.81	2.34	1.71	.42	10.62	77.10	1,719	.....
Dasheen:									
Unpeeled	13343	7.37	2.83	1.60	.77	11.87	75.56	1,714	.....
Peeled	13344	7.38	2.85	1.72	.72	11.69	75.64	1,712	.....
Potato:									
Dried	14816	6.73	2.80	1.93	.57	13.19	74.78	1,724	36.08
Flakes	14819	3.27	2.42	2.34	.62	11.17	80.18	1,798	40.80
Boiled	14870	5.25	2.82	1.98	.50	12.40	77.15	1,749	42.01
Starch	13354	7.13	1.92	2.15	.20	9.81	78.79	1,700	34.60
Sweet potato	13355	5.12	2.61	2.17	.64	10.69	79.06	1,762	.....
Group 2 (grains and cereals):									
Spring wheat	13096	7.17	1.86	2.97	.19	12.63	75.18	1,759	38.29
Yellow corn:									
Raw	13100	6.96	2.01	2.90	.30	11.49	76.34	1,756	35.60
Parched	13098	6.74	1.94	2.88	.46	11.75	76.23	1,757	.....
Steamed	13102	6.06	1.94	3.59	.38	11.69	76.34	1,789	.....
White corn:									
Raw	13099	7.31	2.01	2.70	.32	11.75	75.91	1,744	36.10
Parched	13097	6.99	2.00	3.08	.44	11.69	75.80	1,758	.....
Steamed	13101	6.08	1.86	3.43	.35	11.87	76.41	1,786	.....
Rice:									
Polished	13487	7.47	1.86	1.84	.21	12.00	76.62	1,726	.....
Brown	13809	6.87	2.00	2.84	.25	12.00	74.66	1,758	.....
Buckwheat	13488	7.72	1.95	1.73	.27	11.75	76.58	1,713	.....
Rye (1.1 basis)	13542	9.31	1.99	1.89	.44	13.25	73.12	1,764	.....
Oatmeal	13350	6.93	2.17	4.11	.48	14.00	73.31	1,797	35.29
Feterita:									
Clear	14823	6.35	1.96	2.00	.43	14.12	75.14	1,745	34.89
Patent	14822	7.11	1.93	1.98	.30	12.49	76.19	1,733	36.57
Millet	13657	6.16	2.03	2.78	.27	13.25	76.60	1,789	34.90
Kafir	12302	2.08	2.33	2.14	.51	13.69	79.25	1,819	.....
Milo	12304	1.73	2.18	1.98	.51	13.53	80.07	1,823	.....
Kaoliang	12303	1.71	2.19	1.97	.46	13.66	80.01	1,826	35.63
Barley	18076	6.17	2.08	3.26	.30	11.50	76.69	1,777	.....
Group 3 (legumes):									
Bean, white	13490	7.74	2.70	1.69	.49	15.87	71.51	1,683	.....
Pea, ordinary	13491	8.13	2.35	1.70	.35	16.12	71.35	1,697	.....
Chick-pea	14821	7.31	2.43	2.34	.41	15.75	71.76	1,726	39.24
Peanut	15519	7.78	2.29	13.43	.59	17.38	68.53	2,164	.....
Soy bean	13351	7.33	3.10	7.57	.72	19.50	61.78	1,829	.....
Group 4 (by-products):									
Bran	13349	7.51	2.83	2.33	1.96	14.12	71.29	1,687	37.94
Wheat germ	14824	5.73	3.03	4.70	.57	18.00	70.49	1,842	36.86
Cotton seed, treated	13346	7.37	3.07	3.76	1.55	22.62	61.63	1,725	.....

TABLE 3.—*Analysis of bread, on the 35 per cent water basis.*

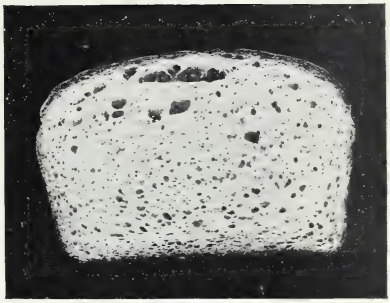
Variety of flour.	Ash.		Fat.	Fiber.	Protein (N × 6.25).	Carbohydrates.	Calories per pound.	Texture.	Color.
	Total.	Salt-free.							
Group 1 (low protein content):	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*			
Chestnut	1.65	0.67	1.57	0.40	8.16	53.22	1,208	84	Gray brown.
Cassava	1.55	.52	1.59	.40	7.33	54.13	1,210	95	Light yellow brown.
Banana:									
Unripe	1.78	.71	1.40	.28	7.33	54.21	1,204	96	Gray brown.
Ripe	1.65	.76	1.20	.29	7.49	54.37	1,210	88	Yellow brown.
Dasheen:									
Unpeeled	1.98	1.00	1.12	.54	8.33	53.03	1,189	85	Gray brown.
Peeled	2.00	.97	1.21	.50	8.25	53.04	1,191	88	Light gray.
Potato:									
Dried	1.95	.95	1.34	.40	9.19	52.12	1,196	88	Light yellow gray.
Flakes	1.62	.82	1.57	.42	7.51	53.88	1,208	80	Yellow gray.
Boiled	1.92	.92	1.36	.29	8.50	52.93	1,200	95	Very slightly grayish.
Starch	1.45	.28	1.50	.14	6.86	55.06	1,215	98	White.
Sweet potato	1.57	.84	1.49	.44	7.33	54.17	1,207	85	Gray brown.
Group 2 (grains and cereals):									
Spring wheat	1.28	.31	2.08	.13	8.74	52.77	1,223	99	Creamy.
Yellow corn:									
Raw	1.40	.38	2.06	.21	8.02	53.31	1,227	95	Yellow.
Parched	1.35	.40	2.01	.32	8.19	53.13	1,224	94	Dark yellow brown.
Steamed	1.34	.40	2.48	.26	8.09	52.83	1,237	96	Yellow.
White corn:									
Raw	1.41	.40	1.89	.22	8.24	53.24	1,223	95	Gray tint.
Parched	1.39	.40	2.15	.31	8.17	52.98	1,227	96	Light yellow brown.
Steamed	1.28	.40	2.37	.24	8.22	52.89	1,237	97	White.
Rice:									
Polished	1.31	.29	1.29	.15	8.43	53.82	1,212	96	Grayish.
Brown	1.39	.42	1.98	.17	8.37	53.09	1,227	94	Pale yellow brown.
Buckwheat	1.36	.40	1.21	.19	8.22	54.02	1,220	84	Light gray.
Rye (1.1 basis)	1.42	.49	1.35	.31	9.50	52.42	1,209	96	Slightly grayish.
Oatmeal	1.51	.57	2.87	.33	9.78	50.51	1,242	98	Yellow gray.
Feterita:									
Clear	1.36	.42	1.38	.30	9.79	52.17	1,211	85	Brown.
Patent	1.35	.41	1.38	.21	8.74	53.33	1,212	88	Gray.
Millet	1.40	.39	1.92	.19	9.18	52.31	1,225	97	Light yellow brown.
Kafir	1.55	.48	1.42	.34	9.09	52.60	1,206	97	Brownish gray.
Milo	1.44	.48	1.31	.34	8.94	52.97	1,207	98	Yellow gray.
Kaoliang	1.45	.51	1.30	.31	9.03	52.91	1,208	96	Red brown.
Barley	1.44	.42	2.25	.21	7.97	53.13	1,232	97	Gray.
Group 3 (legumes):									
Bean, white	1.90	.86	1.19	.34	11.09	50.48	1,201	84	Yellow.
Pea, ordinary	1.66	.67	1.20	.25	11.40	50.49	1,201	79	Yellowish.
Chick-pea	1.70	.72	1.64	.29	11.05	50.32	1,211	94	Pale yellow.
Peanut	1.61	.62	9.45	.42	12.25	41.26	1,394	98	Yellow brown.
Soy bean	2.17	1.17	5.31	.50	13.70	43.32	1,283	85	Rich yellow.
Group 4 (by-products):									
Bran	1.96	1.17	1.64	1.38	9.92	50.10	1,186	92	Gray brown.
Wheat germ	2.08	1.20	3.24	.40	12.41	46.87	1,238	86	Yellow brown.
Cottonseed, treated	2.15	1.23	2.64	1.08	15.87	43.26	1,211	85	Dark brown.
Soy-bean oil cake	2.19	1.32	3.84	.52	14.90	42.25	1,224	.....	

TOTAL ASH.

The breads show a wide variation in the total ash content, from 1.28 to 2.19 per cent, on the basis of 35 per cent moisture. The samples having a total ash content lower than 1.50 per cent include bread made from wheat flour alone, and that from potato starch, as well as the bread from corn, rice, buckwheat, rye, barley, millet, and grain sorghums. Among the breads with an ash content above 1.75 per cent are those made from unripe bananas, dried and boiled potato, dasheen, soy bean, bran, and wheat germ. The lowest total

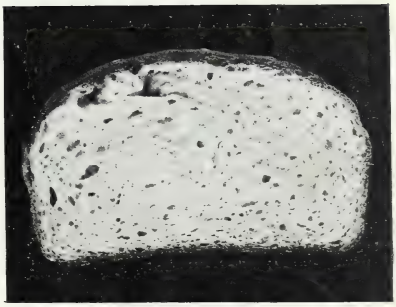


CHESTNUT.



CASSAVA.

BANANA, UNRIPE.

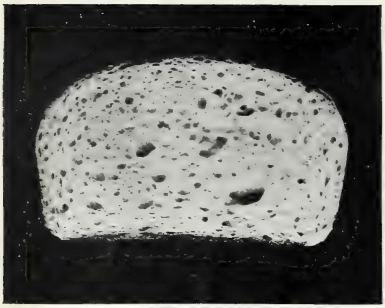


BANANA, RIPE.

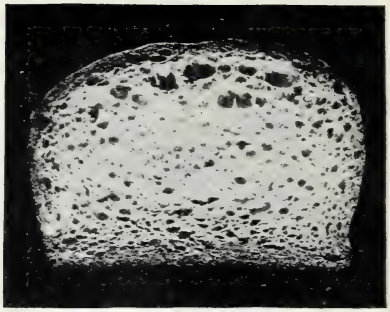
DASHEEN, UNPEELED.

DASHEEN, PEELED.

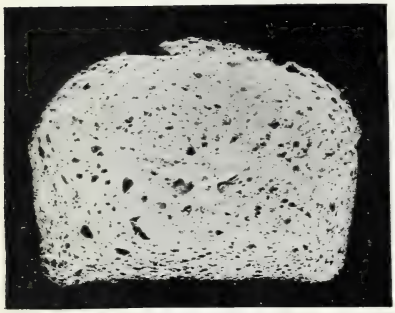
BREADS FROM WHEAT-FLOUR SUBSTITUTES OF LOW PROTEIN CONTENT (GROUP 1).



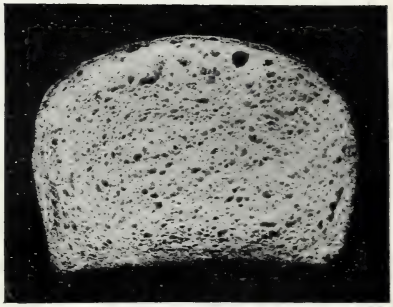
POTATO, DRIED.



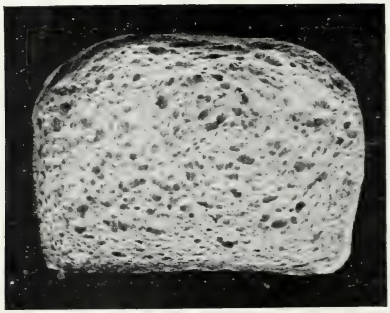
POTATO FLAKES.



POTATO, BOILED.

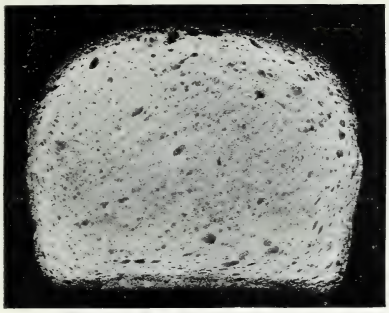


POTATO STARCH.

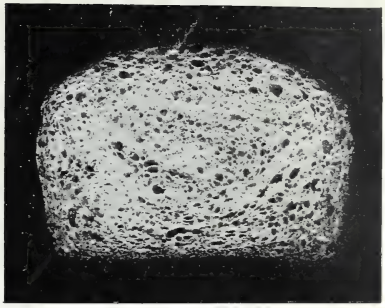


SWEET POTATO FLOUR.

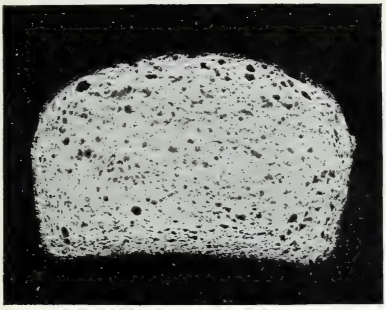
BREADS FROM WHEAT-FLOUR SUBSTITUTES OF LOW PROTEIN CONTENT (GROUP 1).



SPRING WHEAT.



YELLOW CORN MEAL.

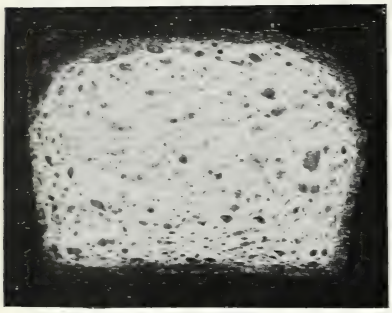


WHITE CORN MEAL.

RICE, POLISHED.

RICE, NATURAL BROWN.

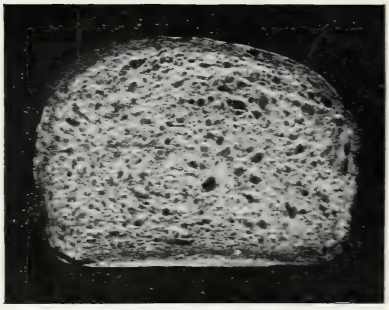
BREADS FROM GRAINS AND CEREALS (GROUP 2).



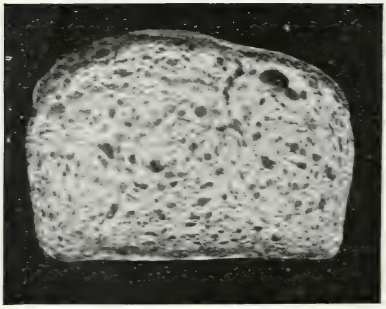
BUCKWHEAT.

RYE.

OATMEAL.

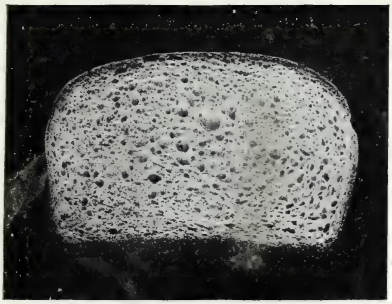


FETERITA (CLEAR).

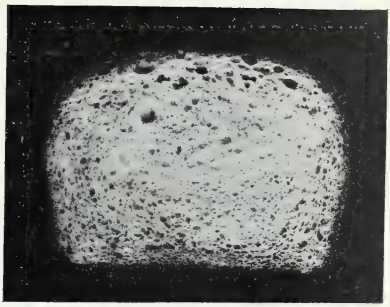


FETERITA (PATENT).

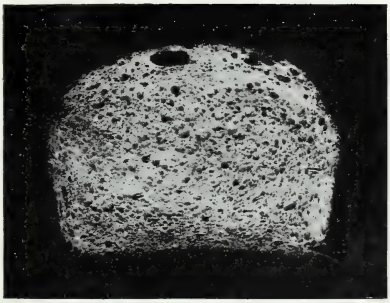
BREADS FROM GRAINS AND CEREALS (GROUP 2).



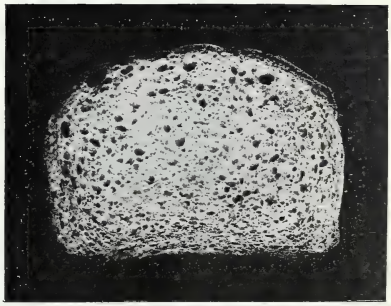
MILLET.



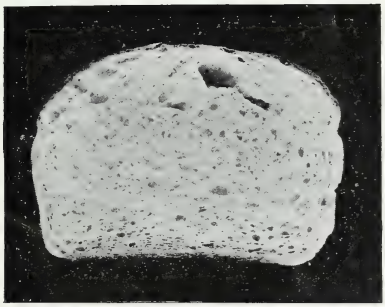
KAFIR.



MILO.

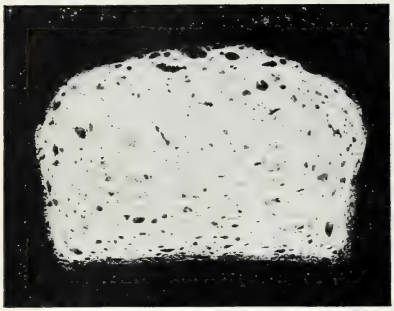


KAOLIANG.



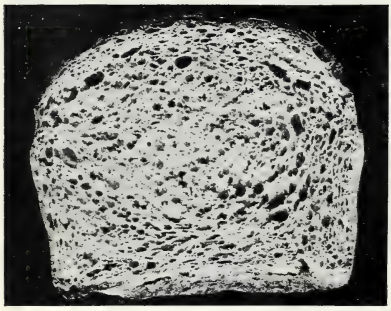
BARLEY.

BREADS FROM GRAINS AND CEREALS (GROUP 2).

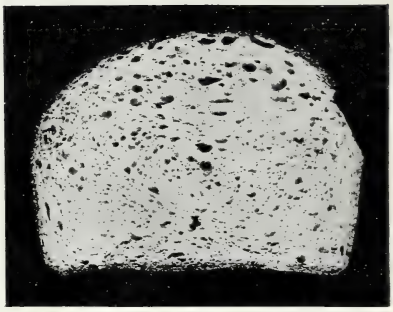


BEAN, WHITE.

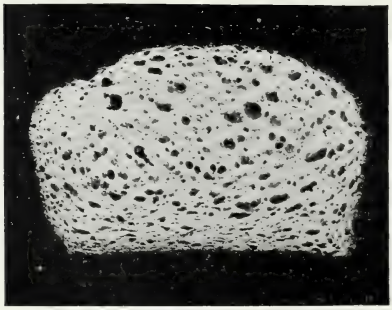
PEA, ORDINARY.



CHICK-PEA.

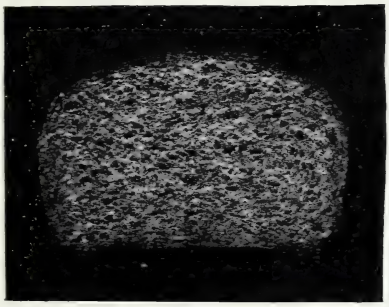


PEANUT MEAL.

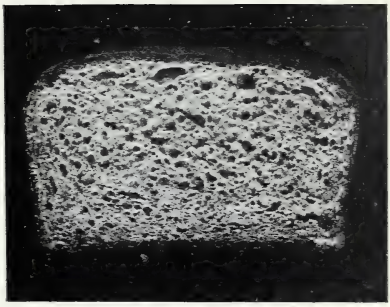


SOY BEAN.

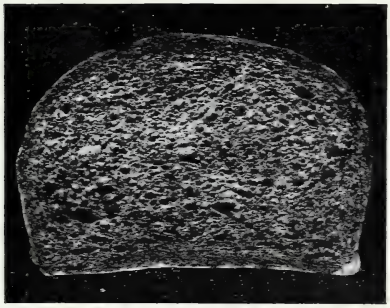
BREADS FROM LEGUMES (GROUP 3).



BRAN.



WHEAT GERM.



COTTONSEED.

BREADS FROM BY-PRODUCTS (GROUP 4).

ash content is found in wheat bread and in bread containing polished rice or starch as an admixture. The breads made from soy bean, wheat germ, and bran had the highest ash content.

SALT-FREE ASH.

In making all of the breads, salt, equivalent to 1.5 per cent of the total flour, was added. If only the total ash content, which includes the added salt, were considered, it might seem that little difference exists in the ash contents of the various breads. For example, the total ash content of the bread made from polished rice flour is approximately the same as that of bread from the brown rice flour, being 1.31 and 1.39 per cent, respectively. Quite different results are given, however, when the ash content is calculated on the salt-free basis. In that case, it is apparent that the polished rice bread could not have more than 0.30 per cent salt-free mineral constituents, while the bread from the natural brown rice would have not less than 0.42 per cent. It is seen also that while wheat-flour bread contains about 0.31 per cent of salt-free ash, bran bread contains 1.17 per cent, almost four times as much.

With the exception of that made from starch, the breads of group 1 are fairly high in salt-free ash. With the exception of that made from barley, rye, oatmeal, and the grain sorghums, the breads of group 2 are generally low in salt-free ash. The breads of group 3 have about the same salt-free ash content as those of group 1. The breads of group 4 and bread from soy-bean flour (group 3) have a very high salt-free ash content, containing about four times as much as the wheat-flour bread, an increase of approximately 300 per cent.

FAT.

The fat content varies from about 1.1 per cent to over 9 per cent. None of the breads of group 1 (those of low protein content) contains much fat. The bread from oatmeal contains almost 3 per cent of fat; that made from wheat-germ flour, a little over 3 per cent; that from soy-bean flour, almost 4 per cent; and that from crushed peanuts (roasted, but not previously pressed), almost 9.5 per cent. The apparent discrepancy in the fat contents of the various breads is due to the fact that, although no fat or shortening was added to the dough, a small amount of shortening was always used on the hands in handling the dough. The amount of shortening thus added to the bread was indefinite, depending upon the character of each individual dough.

FIBER.

The fiber content is very high in the bread made from bran, while in breads made from soy-bean, dasheen, potato, cassava, chestnut, wheat-germ, and peanut flours it is moderately high. In all other

breads it is comparatively low. The fiber content is much higher in bran than in any of the other substitutes used.

PROTEIN.

The average protein content (N×6.25) of the breads belonging to group 1 is less than 8 per cent; of breads belonging to group 2, it is about 8.8 per cent; of those belonging to group 3, it is about 11.9 per cent; while for breads belonging to group 4, it is 12.7 per cent. This protein content varies from less than 7 per cent, in the case of potato-starch bread, to over 15.8 per cent in the case of cottonseed bread. Other breads showing a high protein content are those made from legumes and wheat germ. Breads made with rye, feterita (clear grade), and oatmeal flours are appreciably richer in protein than standard wheat bread. All the breads in groups 3 and 4 are much richer in protein than is the wheat bread. Of group 1, only the bread made from potato flour is richer in protein than all-wheat bread. This, however, was due to the fact that the potatoes used for this experiment happened to be particularly low in starch and high in protein, which would not necessarily be true with potatoes grown in every section of the country.

CALCULATED CALORIC VALUE.

The average number of calories per pound does not differ very much in the various groups of bread. Because of their comparatively high fat content, breads made from peanut and soy-bean flours show a relatively large number of calories per pound, being 1,394 and 1,283, respectively. The bread from oatmeal flour contains 1,242 calories, and that from wheat germ, 1,238 calories per pound. The lowest figures for the caloric value are found among the samples of group 1, and in the case of the bran bread. Bran bread owes its low caloric value to its high fiber or cellulose content. With the possible exception of bread made from peanut, oatmeal, wheat-germ, and soy-bean flours, all of which substitutes contain a large amount of fat, the caloric value of all the breads analyzed is about the same.

TEXTURE, TASTE, AND GENERAL APPEARANCE OF BREAD.

Several of the breads of group 1 have a remarkably fine texture and general appearance. They comprise those made from potato starch, boiled potato, unripe banana, and cassava flour. Those which deserve special attention for their fine flavor are the breads made from chestnut flour, which is rich, nutty, and very agreeable, and from boiled potatoes. The potato bread has the further merit of lending itself well to reheating several days after it has been baked, because it remains moist longer than most other breads. The sweet-potato bread, when made with the usual proportion of sugar, has a

very agreeable, slightly sweetish flavor. Bread made from ripe banana flour also has a sweetish, agreeable, and very characteristic taste, and requires no sugar in its preparation. That made from dried potato flour has a decided potato taste, which makes it much less appetizing than that made from the boiled potato.

Practically all of the breads of group 2 have a very good flavor, although not so marked or characteristic a one as in the case of some of the breads of group 1. The most pronounced flavor was noted in the bread made from rye, from buckwheat, from yellow corn meal and from the sorghum grains. In all other cases the flavor was good, without being too pronounced. The texture of the breads of group 2 ranks very high, several reaching a grade of 95 or over on a standard of 100 for a perfect loaf.

In group 3, the peanut bread easily ranks first both in flavor and in texture. The bread from chick-pea flour is very attractive, being remarkable for its volume and texture, while in taste it is not noticeably different from good wheat bread. Bread made from the Mammoth yellow variety of soy bean has a characteristic beanlike and agreeable flavor, but is not especially good in texture. The bread made from the ordinary dried bean also possesses a characteristic beanlike flavor, which is less marked when the meal is cooked before being used. Bread from dried pea flour has a very agreeable taste.

Every bread of group 4 has a marked flavor peculiar to itself. Bran bread naturally has a characteristic "branny" flavor, which to many is very agreeable. Its color is dark, and its texture fair. The flavor of the wheat-germ bread, while decidedly characteristic, is not unpleasant. It also is dark in color, and does not have a very good texture. Cottonseed-meal bread, even though it contains but 15 per cent of cottonseed meal, has a decided flavor and dark color, although its texture is fairly good.

SUMMARY.

From the salt-free ash determinations it is apparent that all breads containing wheat-flour substitutes (except when starch and rice flour are used) are richer in mineral matter than is wheat-flour bread.

The differences in the fat content of the various breads analyzed are significant only when materials such as the soy-bean or peanut meal (unpressed) are used. The calculated caloric value of the various breads is also so nearly the same that, in general, it will make comparatively little difference, in computing a day's ration on the basis of calories, which bread is taken.

Far more significant is the difference in the protein content. From a value of less than 7 per cent (where starch was used) to one closely approaching 15 per cent (soy-bean bread) is a wide range.

The ideal color of the crumb of wheat-flour bread is creamy. With the exception of breads made with cooked Irish potatoes, polished rice, white corn meal or corn flour, and the pure starches, the color of the mixed breads partakes more or less of the color characteristic of the substitute. Sweet potato and soy-bean meal yield a yellow loaf; banana flour, dasheen, milo, ordinary dried beans, etc., a gray; while many others produce a bread more or less gray brown.

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